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AUTHOR Duncan, Edward M.
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ABSTRACT

The purposes of this experiment were: (1) to examine the development of categorical representations by comparing the performance of children of various ages to adults, and (2) to compare the internal representations of basic level and superordinate categories. Subjects were 48 children (in second, fourth and sixth grades) and 16 adults. The stimulus pictures consisted of 80 line drawings of objects belonging to five categories. On each trial the experimenter orally presented a category name to the subject, then advanced a slide tray exhibiting an arrow which indicated the orientation of the test stimulus. When the subject felt prepared for the test picture, he or she pressed a foot pedal which stopped the timer (measuring preparation time). Approximately one second later the test stimulus was presented, and again the timer was activated and stopped by the response of the subject (measuring discriminative response latency to the test situation). The analysis of the preparation times indicated that superordinate representations are generated and rotated at the same rate as basic level representations. In contrast, the analysis of the response latencies to the test response stimuli revealed that the representations are different. For basic level trials, neither typicality nor response type interacted with the angle of rotation. For superordinate trials, there were significant effects of age level, typicality, and angle of rotation. (Author/MP)

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The Development of Analog and Propositional Representations in Semantic Memory

Edward M. Duncan
University of New Orleans

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One issue in the development of semantic knowledge concerns why children learn to use some categorical terms before others. Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976) suggested that children initially learn to categorize objects at a "basic level" of abstraction. Basic level categories were operationally defined as the most inclusive (or abstract) categories within a taxonomy which contained only instances with similar characteristics. Terms at a higher level of abstraction were defined as superordinate terms and included some instances with few similarities. Both Rosch et al. and Anglin (1977, Exp 2.1) found that children acquired basic level terms at a younger age than superordinate terms.

Since basic level categories are acquired at an earlier age than superordinate categories, it is possible that the mental representations of basic level categories differ from those of superordinate categories. Rosch et al. (1976) suggested that basic level categories are represented by a concrete visual code such as an image. Images may be characterized as "analog" representations because they are assumed to be internally structured in a manner analogous to the structure of objects in the world (e.g., Cooper & Shepard, 1973b; Shepard, 1975). Analog representations are usually contrasted to more abstract representations such as propositional structures (cf., Kosslyn & Pomerantz, 1977; Pylyshyn, 1973).

A superordinate category representation is assumed to be internally structured so that it is similar to the typical exemplars and dissimilar to the atypical instances of the category (e.g., Duncan & Kellas, 1978; Rosch, 1973, 1975). Perhaps the typical instances of a superordinate category are verified as category members in the same manner as stimuli are verified as members of basic level categories. Here the prototypes of superordinate categories could be regarded as analogical representations. On the other hand, atypical instances are accepted as exemplars of superordinate categories even though they seem to be dissimilar to the category prototype. If superordinate categories are also represented in a propositional network, then atypical instances could be verified as superordinate category exemplars by processing information through the propositional network rather than on the basis of analogical information.

The problem with differentiating semantic categories in terms of analogical and propositional models is that several investigators (e.g., Palmer, 1975; Pylyshyn, 1973) have challenged the notion that visual information is processed in an analog

fashion. They maintained that a propositional format is appropriate for representing all knowledge, including visual information. These criticisms have been answered by a number of researchers (Kosslyn, 1975, 1976, 1978; Kosslyn & Pomerantz, 1977; Shepard, 1978; Shepard & Podgorny, 1978) who claim that images function differently in cognition than do propositional representations. A task which seems to provide some direct evidence for a functional view of imagery is the "mental rotation" procedure devised by Shepard and Cooper and their associates (e.g. Cooper, 1975, 1976; Cooper & Shepard, 1973a, 1973b; Shepard & Metzler, 1971).

The present experiment attempted to assess analog and propositional representations of semantic categories in a mental rotation task. There were two purposes of the present experiment. First, it was to examine the development of categorical representations by comparing the performance of children of various ages to adults. There is evidence indicating that basic level terms are acquired at an earlier age than superordinate category names (Anglin, 1977; Rosch et al., 1976) and that superordinate representations change with age (Duncan & Kellas, 1978). The performance regarding superordinate category decisions may depend on the typicality of the category instances, as the effects of typicality have been found to change with age. In order to explicate further the expected differences between basic level and superordinate category primes, the typicality of basic level names relative to their superordinates were varied. Within each superordinate category, the basic level names were selected so that one-half were rated as typical exemplars and one-half as atypical exemplars.

The second purpose of the present experiment was to compare the internal representations of basic level and supercrdinate categories. If the representations of basic level categories are analogical, then the pattern of preparation and response times following basic level names should mirror the responses obtained with visual forms (cf., Cooper & Shepard, 1973b; Cooper & Podgorny, 1976). In constrast, the semantic prototypes of superordinate categories may be thought of as analogical structures which resemble only the typical instances of the category. If so, then the pattern of response latencies following the presentation of superordinate names will depend on the typicality of the category exemplar.

Method

Subjects. A total of 64 subjects from four age groups participated in the experiment. The 48 children were elementary school students recruited from the second, fourth, and sixth grades of schools in the Lawrence, Kansas School District. The 16 adults were volunteers from the Lawrence, Kansas Community.

Stimulus materials. The names of the superordinates and basic level categorie are presented in Table 1.

The stimulus pictures used in the present task consisted of 80 line drawings of the objects belonging to the categories listed in Table 1. There were four different pictures of objects from each basic level category (i.e., four of tables, four of chairs, four of clocks, etc.).

Procedure. On each trial, a subject was presented with both a category name and orientation information. The experimenter presented a category name orally to the subject, and then pressed a button which advanced a slide tray to present an arrow indicating the orientation of the test stimulus. The duration of the presentation of the orientation arrow was controlled by the subject. When the subject felt prepared for the presentation of the test picture, he pressed a foot pedal which stopped the timer measuring the duration of the preparation time. The preparation time was printed and the timer was reset automatically before the presentation of the test stimulus. Approximately one second after the foot pedal was pressed, the test stimulus was presented. Again the timer was activated and was stopped by the response of the subject. Thus, two reaction times were recorded on each trial: (1) the preparation time to the orientation information and (2) the discriminative response latency to the test situation.

Results

Preparation Time. The mean preparation times are presented in Figure 1. The analyses of the preparation times revealed a significant main effects of angle of rotation and a significant interaction of angle of rotation and age level. Subsequent analyses revealed that angle of rotation produced stronger effects with the adults relative to the children.

Reaction Times. The mean reaction times for the subjects in each of the four age groups are presented in Figure 2 (collasped over response type). The results of the analyses of the mean response latencies revealed several significant main effects The overall response latencies decreased with age, the response latencies to typical exemplars were shorter than those to atypical exemplars the response latencies of basic level decisions were shorter than those of superordinate decisions, and the response latencies increased as the orientation of the test stimulus departed from upright. However, all of these significant main effects were qualified by reliable interactions. The significant two-way interaction analysis indicated that the angle of rotation had greater effects on the response latencies of atypical exemplars than those of typical exemplars. There were several significant three-way interactions. The most important of these was the interaction of age level X category type X angle of rotation. The analysis of the superordinate response latencies of the second graders indicated that the mean response latencies increased with orientation whereas the basic level latencies were independent of orientation. The superordinate and bas

level response latencies of the older children and adults were independent of orientation.

In subsequent analyses, the slopes of the linear functions relating superordinate reaction time to angles of rotation were calculated for each subject by the method of least squares. The mean slopes on the typical trials for the second, fourth, and sixth graders and adults was 1.89, -.05, .16, and -.01 msec per degree, respectively. The differences between the means were tested for significance and it was found that mean slope of the second graders were significantly larger than the other mean slopes. The analysis of the slopes on atypical trials revealed no significant effect. The mean slopes of these trials were 1.30, 1.12, .92, and .68 msec per degree for the second, fourth, and sixth graders, and adults, respectively.

Discussion

The analysis of the preparation times indicated that superordinate representations are generated and rotated at the same rate as basic level representations. In contrast, the analyses of the response latencies to the test stimuli revealed that the representations are different. For basic level trials, neither typicality nor response type interacted with the angle of rotation. Furthermore, the average times to make basic level decisions were virtually constant for all angles of rotation.

Linear preparation time functions and flat reaction time functions support the notion that subjects prepare for the anticipated stimulus by generating a mental image from memory and then mentally rotating the image into the expected orientation (cf. Copper & Shepard, 1973b). In general, the present results support the view that basic level representations are analogical in nature. In contrast, the response latencies on superordinate trials indicate that the decisions concerning superordinate category membership differ from those of basic level categories. For superordinate trials, there were significant effects of age level, typicality, and angle of rotation. First, consider the present results in terms of age level. For basic level trials, there was no difference due to the increase in age except for an overall decrease in response latencies. For superordinate trials, however, there was a developmental change in the latencies to make decisions to typical instances.

The developmental change in superordinate decisions is important for several reasons. First, the result is in general agreement with the view that the representation of basic level categories are established early in development (Anglin, 1977; Rosch et al., 1976). The pattern of basic level latencies was the same for the subjects in all of the age groups. Only superordinate decisions changed with development. Secondly, the present results converge on the developmental effects reported by Duncan and Kellas (1978). Duncan and Kellas found that superordinate prototypes of second graders were different from those generated by older subjects.

These findings are in general agreement with a thesis proposed recently by Kosslyn (1978). According to Kosslyn, young children rely predominantly upon imagery in accessing and using information in memory whereas older children and adults rely on both imaginal and abstract representations in memory. In the present experiment basic level representations which seem to be analogical in nature are generated, rotated, and responded to in a similar manner for all the children and adults. On the other hand, superordinate representations apparently consist of both analogical and propositional representations. Both the children and adults generate and rotate superordinate prototypes in a similar manner in preparation for the ensuing test stimulus. However, the response latencies clearly differentiate the superordinate prototypes of second graders from those of the older subjects. When asked to make superordinate decisions, second graders engage in rotational processing when presented either typical or atypical exemplars. Perhaps superordinate decisions, even those concerning typical exemplars, require propositional information as well as analogical information. If so, then young children who have difficulty accessing propositional information may be required to rotate superordinate prototypes to upright before deriving propositional information.

The differentiation between basic level and superordinate decisions can be further explicated by examining the present results in terms of typicality and angle of rotation. These results indicate that subjects generate and rotate a semantic prototype when presented with a superordinate category name. The flatness of the latency function on typical trials suggest that subjects did not engage in rotational processing when a test stimulus of high typicality was presented. Apparently, the superordinate category membership of typical instances can be verified by comparing directly the typical percepts to the rotated superordinate representation. On the other hand, the response latencies of superordinate decisions on atypical trials increased linearly with the angle of rotation suggesting that subjects engaged in rotational processing on these trials. Presumably atypical instances do not resemble prototypes and cannot be verified as superordinate exemplars on the bases of prototypes; rather, atypical instances are verified on the bases of information derived after some sort of mental rotation.

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TABLE 1

Superordinate and Basic Level Names Used in the Present Task

Superordinate Names	Basic Level Names[a]
Furniture	table, chair (1.0) clock, television (4.9)
Vehicles	car, truck (1.2) boat, tricycle (3.4)
Clothing	pants, shirt (1.1) hat, shoes (3.5)
Weapons	cannon, gun (1.5) tank, slingshot (3.0)
Tools	ladder, sawhorse (2.2) wheelbarrow, stapler (4.3)

[a]Numbers in parentheses indicate the mean typicality ratings of the typical exemplars (first line) and atypical exemplars (second line). See Rosch (1973, 1975) for a presentation of the collection and analyses of typicality ratings.

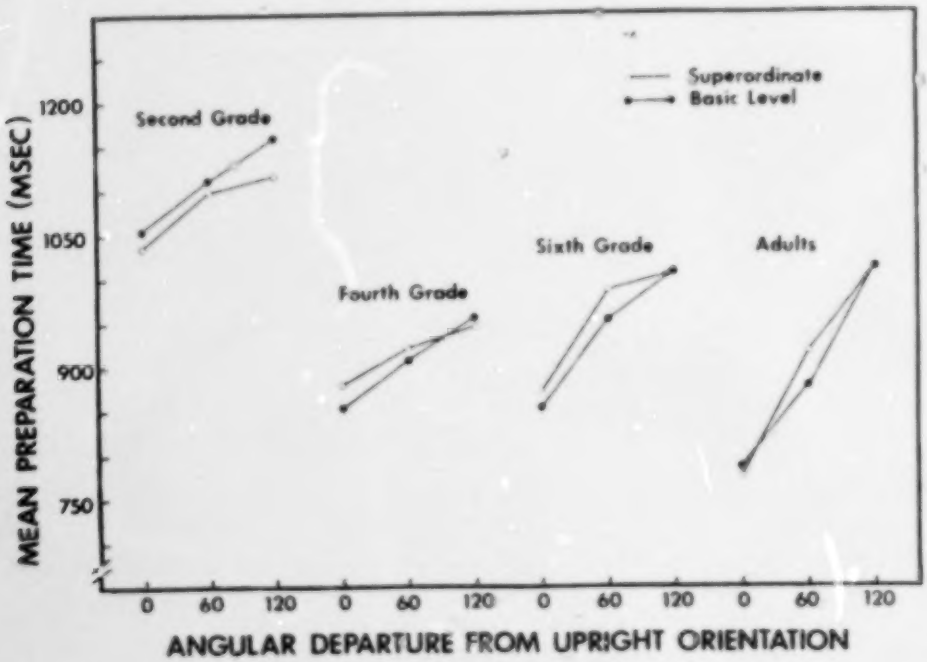

Figure 1. Mean preparation times at each age level for superordinate and basic level names at each angle of rotation.

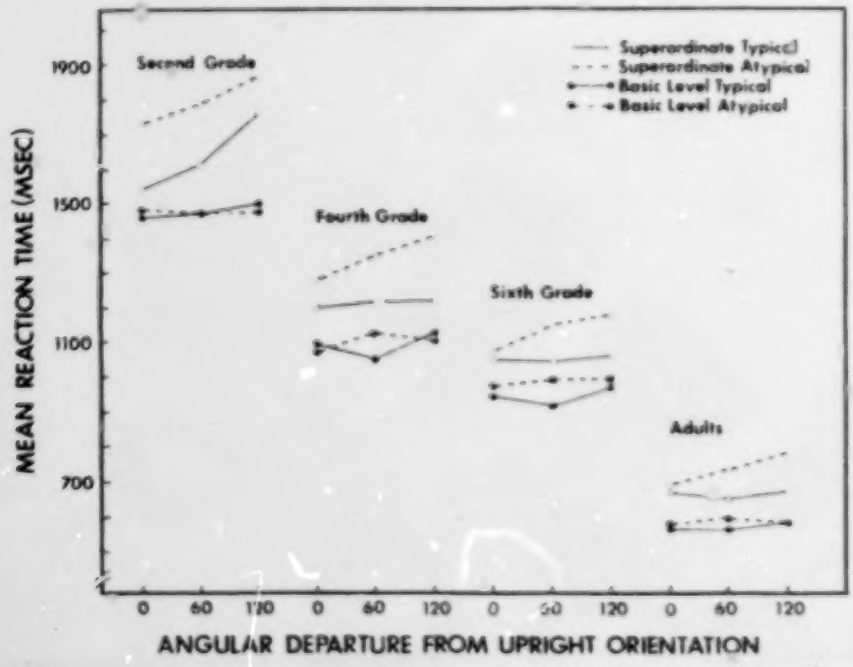

Figure 2. Mean reaction times at each age level for decisions to superordinate and basic level names at each angle of rotation (collapsed over response type).